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Mo' money, mo' problems: Monetary motivation can exacerbate the attentional blink

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Abstract. The *attentional blink* (AB) is a compelling psychological phenomenon wherein observers are less likely to identify a second target (T2) when it appears approximately 200 ms after a first target (T1) in a rapidly presented stream of items. The present investigation examined how monetary motivation could impact the AB when participants were differentially motivated to identify T1 versus T2. Participants completed one of three conditions where the only difference across conditions was a motivational manipulation: a standard AB task (control condition), a motivated condition with T1 worth double the points of T2, or a motivated condition with T1 worth half the points of T2 (points in the motivated conditions were linked to a possible monetary bonus). Motivation had an expected influence on overall performance as both motivated conditions had higher overall T1 accuracy relative to the control condition. More specific to the question at hand, the AB was exacerbated (ie T2 performance was worse shortly after T1) when T1 was worth more than T2. This finding suggests that participants overallocated attentional resources to T1 processing at the expense of T2 processing, and it supports current theories of the AB.

Keywords: visual attention, attentional blink, motivation

1 Introduction

The *attentional blink* (AB) is a compelling psychological phenomenon wherein visible information can fail to be detected. Specifically, when observers view a rapidly presented stream of items, they are less likely to identify a second target shortly after processing a first target (eg Broadbent & Broadbent, 1987; Chun & Potter, 1995; Jolicoeur, 1998; Raymond, Shapiro, & Arnell, 1992). The AB exemplifies the limitations of visual attention and information processing in that a perfectly visible stimulus is less likely to reach conscious awareness if attentional resources are already allocated to processing another target. This effect has been studied in great detail, revealing important aspects about the nature of temporal attention, visual working memory, and conscious awareness (for reviews see Dux, Asplund, & Marois, 2009; Martens & Wyble, 2010).

The AB is a powerful research tool, in part because it produces a reliable response pattern—observers typically show a decrement in second target (T2) accuracy beginning approximately 200 ms after processing a first target (T1). This effect creates a common pattern that can be divided into three measurable components based upon the temporal distance in T2 position following T1 (see figure 1 for an example). First, 'lag-1 sparing' (eg Potter, Chun, Banks, & Muckenhoupt, 1998; Raymond et al., 1992) describes how T2 accuracy is often unimpaired when T2 appears immediately after T1. That is, when items are presented at a rate of one item every 100 ms, the first item appearing after T1 (ie approximately 100 ms after T1; often referred to as 'lag 1') is typically detected without a significant decrement in performance. Second, there is the AB itself, which is a decline in T2 accuracy (compared with T1 accuracy) approximately 200 ms after T1 is processed. Finally, T2 accuracy typically returns to the level of T1 accuracy approximately 500 ms after T1 is presented. This reliable

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and easily reproducible pattern can provide insight into the nature of visual attention and how observers process specific types of visual information (for a full review about properly measuring AB effects see MacLean & Arnell, 2012).

One interesting method to explore the causes underlying the AB effect has been to find stimuli which do not elicit an AB; that is, cases in which T2 accuracy does not reliably drop around 200 ms after T1. Previous work has demonstrated that there is no AB (or a highly reduced AB effect) for arousing words (Keil & Ihssen, 2004); smokers exhibit smaller AB effects for smoking-related words (Waters, Heishman, Lerman, & Pickworth, 2007), and heavy alcohol drinkers exhibit smaller AB effects for alcohol-related stimuli (Tibboel, De Houwer, & Field, 2010). These examples—in particular, the altered AB effects based on addiction—demonstrate how individual differences can affect the size of the AB. Certain long-term activities can likewise alter AB magnitude, or potentially reflect preexisting individual differences in vulnerability to AB via self-selection in participation. For example, videogame players might exhibit a smaller AB than non-videogame players (eg Green & Bavelier, 2003; Oei & Patterson, 2013; but see Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Cain, Prinzmetal, Shimamura, & Landau, 2014), and long-term meditation practitioners exhibit smaller AB effects than nonpractitioners (van Leeuwen, Müller, & Melloni, 2009). These individual differences reflect meaningful changes in cognitive processing as measured by vulnerability to the AB. Through such studies, we can evaluate how various stimuli are processed, compare cognitive changes across time, or even reveal the extent of critical dependencies such as addiction.

The basic AB pattern can also reveal priorities in cognitive processing when certain aspects of the task are manipulated. One such investigative approach involves altering the relative importance of T1 versus another target appearing after T1 (Cousineau, Charbonneau, & Jolicoeur, 2006; Dux et al., 2009). For example, one study emphasized different targets based upon their location in the rapid serial visual presentation (RSVP) stream (eg identify either T1 or identify another target appearing after T1); and while performance was enhanced for the emphasized target, performance declined for the nonemphasized target (Dux et al., 2009). This manipulation nicely altered target relevance in such a way that one target was task-relevant while another was largely task-irrelevant.

1.1 *Motivation and the AB*

A potentially fruitful approach for altering target relevance in an AB task involves motivation. A motivational approach can alter target relevance not through different task goals or physically altered stimuli, but rather by altering the relative importance assigned to each target within a standard AB task. This approach has two primary advantages: first, the motivational relevance (and therefore priority) can be directly manipulated in a controlled fashion; and, second, motivational relevance provides the opportunity to investigate differences in attentional allocation to the various targets without having to change the basic task difficulty or requiring different stimuli.

Previous research has explored the effects of motivation on the AB, though the findings have produced mixed results. On one hand, an AB study monetarily rewarded participants for each target found (participants were rewarded for finding T1 and/or T2, and all targets were equally valued), although this manipulation did not produce a measurable impact on the AB (Olivers & Nieuwenhuis, 2005). On the other hand, the AB was eliminated in another study when the T2 stimulus was previously associated with a high reward. That is, when a T2 stimulus was associated with high reward in a separate task prior to an AB task, the T2 stimulus did not show the standard AB effect (Raymond & O'Brien, 2009).

While the above studies did not vary reward across T1 and T2 in the same AB task, related attentional research suggests that having differently valued targets could change

detection performance for one target over another. For example, spatial visual search tasks have associated one target with a higher monetary reward than another target, and higher-reward targets were found faster than lower-reward targets (Kiss, Driver, & Eimer, 2009; for similar research about value-driven attention see Anderson, Laurent, & Yantis, 2011, 2012). If one target is monetarily rewarded more so than the other in an AB task, how will the relative detection of the two targets be affected? Will monetary motivation boost global performance, or might it selectively enhance performance for one target, and if so, is it at the potential cost of the other?

1.2 *Current study*

The current project had two primary goals. First, this study aimed to clarify the existing literature on motivation and AB, which has produced mixed results. Previous efforts have demonstrated no effect on the AB when the two targets were equally weighted (Olivers & Nieuwenhuis, 2005), or an elimination of the AB when reward-related stimuli from a different task were used (Raymond & O'Brien, 2009). The present study altered the relative importance of T1 versus T2 to clarify how motivational relevance might impact attentional allocation to each target position, which could have either eliminated the blink, exacerbated the blink, or replicated the previous finding of no effect (eg Olivers & Nieuwenhuis, 2005). Second, this study aimed to inform how weighting differences between T1 and T2 might affect the blink. Previous research has demonstrated that physically altering T1 to affect its relative difficulty can increase AB magnitude (eg Ouimet & Jolicoeur, 2007). Physically altering stimuli can affect the difficulty in processing one stimulus over another (eg Dux et al., 2009), whereas a motivation manipulation can alter target relevance without making any changes to the stimuli or task difficulty. Thus, the present study offers an investigation into attentional weighting based solely on internal relevance for the observer rather than physical differences in the stimuli or individual differences between observers.

The present study investigated the AB when participants were differentially motivated to identify T1 versus T2. Participants completed a standard AB task in one of three conditions: the 'control' condition wherein they were simply paid for their participation with no performance incentives; the 'T1-worth-more' condition where they received points for correctly identifying T1 and T2, with T1 worth double the points of T2; or the 'T2-worth-more' condition where they received points for correctly identifying T1 and T2, with T2 worth double the points of T1. Previous research has shown that a point system is capable of inducing positive intrinsic motivation (eg Miranda & Palmer, 2014), and here we further enhanced motivation by relating a point system to a monetary incentive—an additional US \$50 was rewarded to the individual who accumulated the most points in his or her particular group for the two motivation conditions (see section 2 for details). Notably, all participants completed the same task, with the same stimuli, and the only difference was the nature of their motivation. Thus, the motivation manipulation did not change the physical nature of the task; nor did it make either target task-irrelevant as participants in the motivated conditions received points for identifying each target.

2 Method

2.1 *Participants*

Participants for the control condition were recruited as a part of another larger project, which included fifty-seven total participants. Of the fifty-seven participants, twenty-three received course credit for their time, and their data were not analyzed here (to maximally compare the control condition with the motivated conditions, we limited analyses to only those participants who were monetarily compensated for their time). Data from one participant were excluded for a T1 accuracy rate more than 2.5 standard deviations below the mean of the control condition.

Thus, our control condition included data from thirty-three participants (age: $M = 21.65$ years, SD = 1.96 years; seventeen female, fourteen male, two did not answer the gender question), who participated for US $10 per hour without any further reward structure.

Motivated participants were randomly assigned to one of the motivation conditions (T1-worth-more; T2-worth-more) and received US $10 per hour for completing the experiment. Each participant was informed that the individual who accumulated the most points in his or her particular group would receive an additional US $50. Each motivation condition was split into three different subgroups solely for the purposes of the US $50 reward so that each participant knew they were competing with approximately ten other participants for the best score (ie there were six total US $50 prizes). Data from one participant (in the T1-worth-more condition) were excluded for a T1 accuracy rate more than 2.5 standard deviations below the mean of the specific condition. Thus, data from thirty-two participants comprised the T1-worth-more condition (age: $M = 20.53$ years, SD = 2.21 years; eighteen female), and data from thirty-two participants comprised the T2-worth-more condition (age: $M = 20.59$ years, SD = 1.54 years; twenty-four female).

2.2 *Stimuli and apparatus*

The stimuli were white numbers or letters (Arial font, 1.0 deg visual angle, with participants seated approximately 57 cm from the computer screen without head restraint) on a black background at the center of the display. Distractors were numbers randomly drawn from the digits two through nine. Targets were randomly drawn from all capital letters, excluding B, I, O, and Q.

Participants were tested on either a Dell Vostro 260 computer with a 23.6-inch widescreen LCD monitor or a Dell Inspiron computer with a 20-inch CRT monitor. Stimuli were presented in the same size at the center of the display on both displays, and the only difference was how far the solid black background extended to reach the edges of the screen. Matlab software (The MathWorks, Natick, MA) and the Psychophysics Toolbox version 3.0.8 (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997) were used for stimulus presentation and data collection.

2.3 *Design and procedure*

The task was identical in all three conditions and based on a standard AB task (Chun & Potter, 1995). Each trial began with a fixation dot (0.25 deg in diameter, white on the black background) at the center of the screen that remained on-screen until the participant pressed the space bar. Each trial consisted of a RSVP stream of 16 items, each presented for 100 ms. T1 appeared between the third and seventh temporal positions, and T2 appeared one to eight positions after T1. Thus, across the experiment, T1 and T2 could appear at many of the same possible temporal positions in the 16-item RSVP stream. The position at which T2 appeared following T1 is referred to as a 'lag' (eg lag 3 represents T2 appearing 3 positions in the RSVP stream following T1). Neither the first two items nor the last item in the RSVP stream was ever a target (participants were not informed of this manipulation). Additionally, T1 and T2 could never have the same letter identity on a trial (ie T1 and T2 would never both be the letter 'E'). Participants completed 10 practice trials before 200 experimental trials. 80% of trials had two targets, and 20% had one target (participants were not informed of the trial distribution). Dual-target trials were divided equally among the eight possible lag positions following T1. Responses were made with a key press of the corresponding letter(s) on the keyboard following the RSVP stream. No feedback was given, and the number of points accumulated was provided only at the end of the experiment (to hold motivation constant throughout the experiment).

Participants in the control condition performed the task with no points assigned to either target. In the motivation conditions participants received points for correctly identifying T1 and T2, and T1 was worth 10 points in both conditions. T2 was worth 5 points in the

T1-worth-more condition, and T2 was worth 20 points in the T2-worth-more condition. Participants received points for T2 only if they correctly identified T1; this was done to prevent participants, particularly those in the T2-worth-more condition, from treating our task like an ignore T1 condition (eg Raymond et al., 1992).[1] For single-target trials that did not contain a T2, participants received the same number of points for correctly identifying that no T2 was present (via pressing the space bar) as if they had correctly identified T2, which served to discourage participants from randomly guessing to accumulate more points.

A recent article (MacLean & Arnell, 2012) has provided a roadmap for designing valid AB paradigms that minimize methodological concerns. Our paradigm fulfilled the prescribed parameters as there were T1 and T2 masks (every target item was both preceded and followed by a distractor), and there were T2 positions for at least one short lag (<500 ms, but not lag 1) and at least one long lag (>500 ms).

2.4 *Planned analyses*

Our primary measure of interest was the AB magnitude, and the prior literature provides a plethora of ways to calculate it (especially given that the current study included eight possible T2 positions following T1). MacLean and Arnell (2012) suggested that a lag-dependent effect on T2 performance should compare T2 performance at an appropriately short lag versus a sufficiently long lag (see MacLean & Arnell, 2012, for further details on how the AB should, and should not, be calculated). Given the current design, we can fulfill all the appropriate criteria by comparing a short-lag T2 position (<500 ms) that is not lag 1 with a long-lag T2 position (>500 ms). These requirements provide three candidate short lags (lags 2–4) and four candidate long lags (lags 5–8). To minimize experimenter bias in determining which specific short-lag and long-lag positions to use for measuring the AB, we used a statistical procedure to select appropriate lag positions. T2 lag positions were selected for analysis as the first lag position, on average, to show a significant difference from overall T1 accuracy (thus demonstrating the beginning of the AB), and the next subsequent lag position where accuracy was not significantly different from T1 (thus demonstrating when performance recovered; see table 1). The analysis was collapsed across all three groups, and lag 5 was the

Table 1. Raw data for T2 accuracy separated by experimental condition and T2 position. Additionally, a '*' or '−' denotes a statistically significant or nonsignificant comparison with overall T1 accuracy by experimental condition and T2 position. Note: T1-WM represents T1-worth-more, and T2-WM represents T2-worth-more.

T2 position	Condition/%		
	control	T1-WM	T2-WM
Lag-1	87.70 (2.38)−	92.06 (1.63)−	93.22 (1.14)−
Lag-2	76.14 (2.58)*	68.72 (4.16)*	74.30 (3.68)*
Lag-3	79.00 (2.75)*	74.98 (3.78)*	78.07 (3.99)*
Lag-4	84.92 (2.89)*	85.97 (2.41)*	86.11 (3.14)*
Lag-5	89.04 (2.14)−	95.71 (0.94)−	92.50 (1.32)−
Lag-6	90.07 (1.93)−	96.61 (0.65)*	96.46 (0.87)*
Lag-7	92.04 (1.81)−	96.44 (0.81)*	95.69 (0.85)*
Lag-8	93.45 (1.25)*	95.45 (0.83)−	97.03 (0.63)*

Note: * = $p < 0.05$, − = $p > 0.05$.

[1] We also ran another experiment to compare whether the findings were influenced by the requirement that participants first identify T1 to receive points for T2. See "Additional control experiment" in subsection 3.2.2.

first T2 position after 200 ms to not be significantly different from overall T1 accuracy (ie performance had recovered to the baseline measure) ($t_{96} = 0.47$, $p = 0.64$). The comparison between overall T1 accuracy and lag-5 accuracy was also nonsignificant across conditions (control: $t_{32} = 0.68$, $p = 0.50$; T1-worth-more: $t_{31} = 1.22$, $p = 0.23$; T2-worth-more: $t_{31} = 1.24$, $p = 0.22$). Thus, this selection process resulted in the AB being defined as the difference in T2 accuracy between lag 2 and lag 5 given that T1 was correctly identified.

3 Results

3.1 *T1 accuracy*

3.1.1 *Overall T1 accuracy.* T1 appeared on every trial (both single-target and dual-target trials), which provides an overall baseline measure of performance across conditions. To first examine the general role of motivation on performance, we conducted a one-way ANOVA on overall T1 accuracy with condition (control, T1-worth-more, T2-worth-more) as the between-subjects factor. There was a significant main effect of condition for overall T1 accuracy (control: $M = 90.09\%$, SE = 1.09%; T1-worth-more: $M = 94.19\%$, SE = 0.70%; T2-worth-more: $M = 94.06\%$, SE = 0.82%) ($F_{2,94} = 8.31$, $p < 0.001$, $\eta_p^2 = 0.15$). The control condition had lower T1 accuracy than the T1-worth-more condition ($t_{63} = 3.14$, $p < 0.01$) and lower T1 accuracy than the T2-worth-more condition ($t_{63} = 3.26$, $p < 0.01$) (see table 2). There was no difference between the T1-worth-more and T2-worth-more conditions ($t_{62} = 0.14$, $p = 0.89$).

Table 2. Accuracy by condition, and depiction of statistically significant and nonsignificant comparisons, for single-target accuracy, dual-target T1 accuracy, dual-target T2 accuracy (across all eight possible lags), and the attentional blink (T2 accuracy at lag 2 versus lag 5). Note: T1-WM represents T1-worth-more, and T2-WM represents T2-worth-more.

	Condition/%			Comparisons (* = significant)		
	control	T1-WM	T2-WM	control with T1-WM	control with T2-WM	T1-WM with T2-WM
Single-target trials	90.68 (1.28)	93.67 (1.14)	93.20 (1.16)	−	−	−
Dual-target T1 accuracy	89.94 (1.15)	94.32 (0.69)	94.28 (0.52)	*	*	−
Dual-target T2 accuracy	86.57 (1.49)	88.83 (1.15)	90.14 (1.20)	−	−	−
Attentional blink	12.90 (3.02)	26.99 (3.87)	18.20 (3.17)	*	−	−

Note: * = $p < 0.05$, − = $p > 0.05$.

3.1.2 *Single-target trials.* Single-target accuracy was defined as the hit rate for the single-target present on these trials. Single-target accuracy data (see table 2) were submitted to a one-way ANOVA with condition as a between-subjects factor, and there was no significant difference between conditions (control: $M = 90.68\%$, SE = 1.28%; T1-worth-more: $M = 93.67\%$, SE = 1.14%; T2-worth-more: $M = 93.20\%$, SE = 1.16%) ($F_{2,94} = 1.83$, $p = 0.17$).

Given that no second target was present in the single-target trials, it was possible that participants could strategically guess an identity for a ‘T2’ to acquire more points—in which case, they would be less likely to indicate that no second target was present. However, there was no significant difference across conditions in correct rejections—when participants correctly identified T1 and no T2 was present (control: $M = 88.15\%$, SE = 2.70%; T1-worth-more: $M = 90.57\%$, SE = 2.82%; T2-worth-more: $M = 93.57\%$, SE = 1.40%) ($F_{2,94} = 1.29$, $p = 0.28$).

3.1.3 *Dual-target trials.* There was a significant main effect of condition for T1 accuracy on dual-target trials ($F_{2,94} = 9.09$, $p < 0.001$, $\eta_p^2 = 0.16$), with lower accuracy for the control condition than the T1-worth-more condition ($t_{63} = 3.26$, $p < 0.01$) and lower accuracy for the control condition than the T2-worth-more condition ($t_{63} = 3.43$, $p < 0.01$) (see table 2). There was no difference between the T1-worth-more and T2-worth-more conditions ($t_{62} = 0.05$, $p = 0.96$).

3.2 *T2 accuracy*

3.2.1 *T2 accuracy.* There was a significant main effect of condition for blink magnitude ($F_{2,94} = 4.47$, $p = 0.01$, $\eta_p^2 = 0.09$) (see figure 1). Participants in the T1-worth-more condition had a larger AB than participants in the control condition ($t_{63} = 2.88$, $p < 0.01$) and a marginally larger AB than participants in the T2-worth-more condition ($t_{62} = 1.76$, $p = 0.08$) (see table 2), and there was no difference between the T2-worth-more and control conditions ($t_{63} = 1.21$, $p = 0.23$).

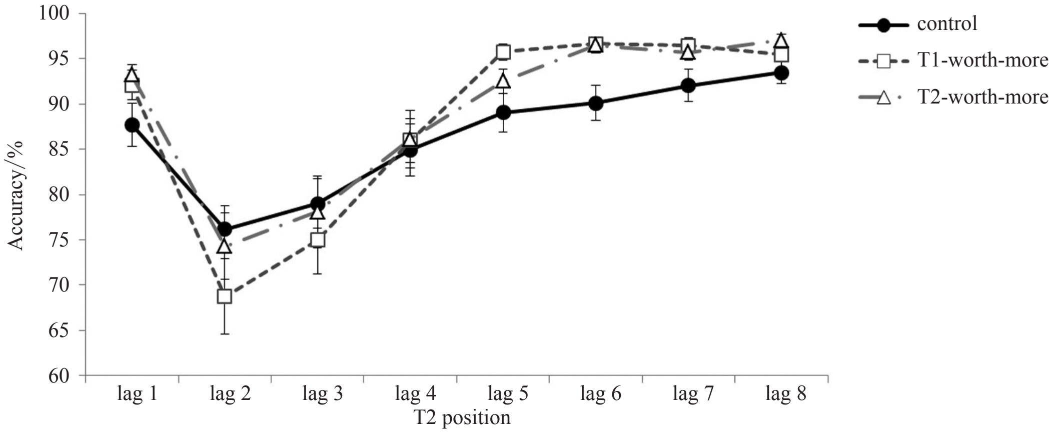

Figure 1. T2 accuracy across the eight possible lag positions by condition. Horizontal lines represent overall T1 accuracy for each condition. Error bars represent standard error.

Following MacLean and Arnell's (2012) prescription for measuring an AB effect, we tested for a possible interaction between experimental conditions across the critical T2 lags. A 3 × 4 mixed-model ANOVA with experimental condition (T1-worth-more, T2-worth-more, or control) as a between-subjects factor and T2 position (lags 2–5) as a within-subjects factor produced a significant interaction ($F_{6,282} = 2.44$, $p = 0.03$, $\eta_p^2 = 0.05$). This supports the above analysis that demonstrated a larger AB effect for the T1-worth-more condition than either the control or T2-worth-more conditions. Note that only lags 2–5 were used in this analysis to avoid the inclusion of lag-1 sparing effects or ceiling effects at later lags (see MacLean & Arnell, 2012).

As described in the planned analyses section above, the AB was assessed as the T2 accuracy difference between lags 2 and 5. However, more information can potentially be gleaned by examining lags 6–8. A 3 × 3 ANOVA with experimental condition (control, T1-worth-more, or T2-worth-more) as a between-subjects factor and T2 position (lags 6–8) as a within-subjects factor produced a significant main effect of condition ($F_{2,94} = 7.78$, $p < 0.001$, $\eta_p^2 = 0.14$), but no main effect of lag position ($p = 0.44$) and no interaction ($p = 0.11$). T2 accuracy in the T1-worth-more condition was higher than in the control condition ($t_{63} = 2.83$, $p < 0.01$), and T2 accuracy in the T2-worth-more condition was higher than in the control condition ($t_{64} = 3.05$, $p < 0.01$). There was no difference between the T1-worth-more and T2-worth-more conditions ($t_{62} = 0.31$, $p = 0.76$). These findings align with the T1 accuracy in dual-target trials results in that the motivated participants performed more accurately than unmotivated participants.

Further, these results demonstrate that motivation improved accuracy performance both before the AB occurred (as evidenced by the single-target-only baseline comparisons) and after AB recovery (as evidenced by T2 performance at lags 6–8).

3.2.2 *Additional control experiment.* In the motivation conditions participants received points for T2 only if they accurately identified T1. This was done to ensure that participants in the T2-worth-more condition did not approach the experimental task as an ignore-T1 task (eg Raymond et al., 1992). However, this manipulation could potentially blur the lines between the T2-worth-more and T1-worth-more conditions—if participants could not receive points for identifying T2 without first identifying T1, then some of T2's attentional value could be attributed to T1. To test whether the T2-worth-more cond ition was affected by this manipulation, we conducted an additional T2-worth-more experiment wherein participants received the full points for correctly identifying T2 even if they did not correctly identify T1. Nineteen participants completed the experiment with the same instructions and monetary motivation as the original T2-worth-more condition (US $50 bonuses were provided to the two participants who accumulated the most points out of a group of approximately ten participants). The results were not significantly different from the original T2-worth-more condition on single-target T1 accuracy, dual-target T1 accuracy, or T2 accuracy at any lag position (all ps > 0.10). Likewise, there were no significant differences for AB magnitude ($p = 0.17$), average T2 accuracy after AB recovery (average of lags 6–8; $p = 0.49$), or lag-1 sparing ($p = 0.73$). Therefore, we can conclude that the T2-worth-more condition was not affected by the requirement that participants had to accurately identify T1 to receive points for T2.

3.2.3 *Lag-1 sparing*. Previous work has shown that T2 accuracy in an AB task is often unimpaired at the first lag position following T1 (ie within 100 ms), which is referred to as lag-1 sparing (eg Potter et al., 1998; Raymond et al., 1992). We measured lag-1 sparing by comparing T2 performance at lag 1 versus lag 2, and there was a significant main effect of condition ($F_{2,94} = 3.18, p = 0.05, \eta_p^2 = 0.06$), with the T1-worth-more condition demonstrating greater lag-1 sparing ($M = 23.34\%$, SE = 3.64%) than the control condition ($M = 11.56\%$, SE = 2.48%); $t_{63} = 2.67, p = 0.01$). There was no significant difference between the T2-worth-more ($M = 18.92\%$, SE = 3.81%) and control conditions ($t_{63} = 1.62, p = 0.11$), or between the T1-worth-more and T2-worth-more conditions ($t_{43} = 0.84, p = 0.41$).

4 General discussion

The AB phenomenon highlights the attentional limitations of the human visual system—processing one item can dramatically impair the ability to process a subsequent item. To better understand these attentional limitations, the current study introduced a motivational manipulation into a standard AB task to examine if top-down influences could dampen, or perhaps even exacerbate, the AB effect. While monetary motivation improved general performance (eg overall T1 accuracy), it also had a negative impact by exacerbating the AB when T1 was relatively more valuable than T2. Moreover, motivation enhanced performance for single-target trials, and late lag positions for T2—demonstrating enhanced performance both before and after, but not during, the critical AB period.

It is particularly interesting that the present study observed both a positive and negative impact of a monetary reward, which does conflict with some previous evidence regarding motivation and AB effects. For example, one prior study found that motivation could eliminate an AB effect if the T2 stimulus was associated with a higher reward in a separate task (eg Raymond & O'Brien, 2009), whereas the current study demonstrated that motivation could exacerbate the AB effect. There are several potential reasons for this difference in results, but one candidate cause might be how the motivation was introduced. The Raymond and O'Brien (2009) task used a stimulus-specific reward, which has stronger parallels to other

examples of reduced or eliminated AB with specific stimuli (eg reduced AB for smokers with smoking-related words; Waters et al., 2007). Alternatively, the current study implemented a global motivation manipulation without a stimulus-specific component.

A previous AB study manipulated motivation without stimulus-specific rewards (Olivers & Nieuwenhuis, 2005), which is closer to the manipulation used in the current study. Interestingly, this prior study's reward structure—equivalent rewards for identifying T1 or T2—did not produce an effect on the AB, whereas the current study found that providing different rewards for T1 and T2 could significantly exacerbate the AB. Collectively, it appears that the impact of motivation on the AB can arise from stimulus-specific rewards or differentially motivating participants to identity either T1 or T2.

Another notable difference between the present study and the existing literature is that previous studies sought to limit an overexertion of attentional resources by adding complications to the task (eg Olivers & Nieuwenhuis, 2005, 2006; Taatgen, Juvina, Schipper, Borst, & Martens, 2009). For example, participants could no longer emphasize T1 processing because their cognitive resources were devoted elsewhere, such as when the participant listened to music (Olivers & Nieuwenhuis, 2006). The current approach utilized a complementary, but mechanistically opposite, approach—for the T1-worth-more condition, T1 processing was emphasized rather than minimized by making it relatively more important than T2. This outcome is in line with previous work which found that physically altering T1 to affect its relative difficulty could increase the AB (Ouimet & Jolicoeur, 2007). Note, though, that a key difference here is that the AB magnitude was significantly affected without manipulating any of physical attributes of the stimuli.

One potential explanation for the observed findings is that motivation (or other like factors) may be able to alter how much a particular target stands out to a participant (ie the target's salience). Previous work, both with an AB task (eg Raymond & O'Brien, 2009) and with other cognitive tasks (eg Biggs, Kreager, Gibson, Villano, & Crowell, 2012), suggests that top-down influences can affect how much a given stimulus stands out for a given observer. Such top-down modulations of attentional allocation, which are driven by prior knowledge and affect regarding specific stimuli, cannot account for the current results given that any letter could appear as T1 or T2 in the AB stream. Rather, it appears that motivation affected performance here by altering attentional allocation such between targets. This finding demonstrates that motivation can significantly influence an AB task in addition to demonstrating that attentional weighting can be altered through internal priorities without changing the stimuli or making one target largely irrelevant.

Monetary motivation offers a nice parallel to other AB-like research involving emotion and other forms of motivation. For example, the emotion-induced blindness paradigm (Kennedy, Rawding, Most, & Hoffman, 2014; Most, Chun, Widders, & Zald, 2005; Most & Wang, 2011; Wang, Kennedy, & Most, 2012) demonstrates how emotion-related stimuli can cause an AB-like effect when presented in rapid sequence. In one study emotionally negative images such as a threatening animal (eg a snake ready to bite) were found to impair detection of a target that appeared shortly after the emotionally negative image (Kennedy & Most, 2012). The motivation in such a paradigm could be interpreted as survival based—there is a high incentive to detect any predators or general threats in the immediate environment. Likewise, motivation can arise from other forms beyond monetary reward, such as from hunger. Appetite can create an intrinsic reward that impacts attention in various ways, and it has been found that food stimuli can create a larger AB for hungry observers compared with satiated observers (Piech, Pastorino, & Zald, 2010) and that food images cause increased distraction for hungry observers in a visual search paradigm (Biggs, Kreager, & Gibson, submitted). These forms of motivations

can alter attentional processing—much in the same way that a point structure with potential monetary reward was found to alter target processing in an AB paradigm here.

The current findings align with two general categories of AB theories. The first is a filter-based account of AB where the blink arises due to a 'filter' of information into working memory not allowing the T2 item to pass into working memory while T1 is being processed (eg Olivers & Meeter, 2008; Raymond et al., 1992; Taatgen et al., 2009). For example, the 'boost–bounce' theory (Olivers & Meeter, 2008) would predict that participants allocate too many attentional resources to processing T1, which in turn generates a greater 'bounce' (ie inhibition of T2 processing) if T2 appears during the blink window. If there is an attentional 'boost' to facilitate processing, then increased motivation to process T1 may further exacerbate the discrepancy between T1 and T2 processing—thereby boosting the 'boost' and making the 'bounce' even more pronounced. The boost–bounce theory would further predict why there was greater lag-1 sparing—a greater attentional 'boost', caused by higher motivation for T1, would spread to the lag-1 position. Another filter-based theory attributes the AB to cognitive control (eg the threaded cognition theory; Taatgen et al., 2009), which requires an alternative interpretation as to how motivation could affect the AB. The control process suppresses target detection while the memory for the first target is being consolidated, which prevents accurate T2 detection until T1 is fully processed (for a theoretically similar stance, see Di Lollo, Kawahara, Ghorashi, & Enns, 2005). If T1 is worth more than T2, then T2 suppression could be enhanced to ensure that T1 is thoroughly processed.

The second broad category of AB theories that the current data align with are resource-depletion-based theories that suggest an increase in AB magnitude reflects a depletion of cognitive resources while T1 is being processed. This resource depletion either prevents T2 retrieval from working memory (eg the interference theory; Shapiro, Raymond, & Arnell, 1994) or prevents T2 from entering working memory in the first place (eg the bottleneck theory; Chun & Potter, 1995). With respect to these theories, the T1-worth-more condition likely led participants to allocate even more resources to T1 processing because T1 was relatively more valuable than T2, leaving less available for T2 processing (for theoretically similar stances see Jolicoeur & Dell'Acqua, 1998; Ward, Duncan, & Shapiro, 1996).

5 Conclusions

Motivation has been shown to positively influence attention, revealing benefits such as enhanced executive control abilities (eg Robinson et al., 2012), better perceptual sensitivity (eg Engelmann, Damaraju, Padmala, & Pessoa, 2009), and improved spatial visual search accuracy (eg Clark, Cain, Adcock, & Mitroff, 2014). Unlike previous studies on motivation and AB (Olivers & Nieuwenhuis, 2005; Raymond & O'Brien, 2009), we demonstrated here that monetary motivation can actually have a detrimental effect upon performance when participants are differentially motivated to process T1 over T2.

The current evidence supports the idea that motivation is not always the best way to improve performance, and that motivation could, at times, have negative impacts. For example, a detrimental impact of motivation has been observed in a 'go/no-go' task—when participants were rewarded for responding with a 'go' signal, their 'no-go' (ie inhibitory responses) were slowed (Padmala & Pessoa, 2010). Another recent finding demonstrated how avoidance motivation—to avoid a punishment rather than to receive a reward—could impair memory performance in spatial learning (Murty, LaBar, Hamilton, & Adcock, 2011). Taken together, these findings and our current evidence suggest that motivation is not uniformly beneficial. Both the context and specific method of motivating participants must be taken into account when attempting to improve task-related performance through motivation. At least in the current case, it appears that Notorious B.I.G. and Puff Daddy had it right all

along—“the more money we come across, the more problems we see” (B.I.G., Daddy, Ma$e, Edwards, & Rodgers, 1997).

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